

Patenting propensity across sectors: Analysis of its variance in the advanced economies

**Manuel Mira Godinho (*)
Guilherme Rebelo**

(*) Corresponding author: mgodinho@iseg.utl.pt

The authors are both affiliated to
ISEG - Instituto Superior de Economia e Gestão
(Technical University of Lisbon, Portugal)
and CISEP

Abstract

The aim of this investigation is to analyze the relationship between the variance of patenting propensity across different industrial sectors and the possible determinants of that variance in 10 economies (US, Canada, Japan, France, Italy, Germany, UK, Finland, Netherlands and Denmark). Until recently such analysis would not be possible. Patent statistics have been organized according to a technological classification, while economic statistics are organized according to the sectoral affiliation of firms. However, the recently published "OECD Technology Concordance - OTC" database has made available patenting data on a sectoral level. The original source of the OTC information is the European Patent Office. The analysis we carried out related the sectoral OTC data with information about the possible determinants of patenting. A concordance matrix had to be built to make compatible information stemming from 6 different sources. The econometric model that was run separately for each country assumed the log-log or the log-lin form with average values for years 93/94/95/96. The dependent variable has been alternatively represented by "patents per employee" and "patents/GVA". The explanatory variables were: APP (effectiveness of patents to appropriate the returns on innovation); EFFORT (R&D intensity); SIZE (dimensional distribution of firms in each industry); and X/O (export propensity). The econometric estimation revealed that APP and EFFORT are significant for most economies, while X/O tends to be statistically significant only for non-EU countries. Finally SIZE despite always non-significant has a negative impact on patenting. The paper finalizes with the implications of these results for both innovation theory and policy formulation.

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1. Introduction

The interest on understanding the determinants and implications of patenting activities of firms, industries and nations has risen continuously over the recent decades. This interest is equally shared by the academic, business and policy making communities. There are several reasons for this growing interest. Firstly, the fact that economists have had no perfect indicators of the innovation process led them to take patent counts as a good proxy of innovative output (Griliches, 1990). Secondly, the patent explosion that took off in the middle 1980s has contributed to that interest. More recently yet, the recognition that most of the stock market value of firms stems from their intangible assets, ranking patents highly on those intangibles, has further contributed to that interest.¹

Patent analysis has however faced several difficulties. One of them has to do with the fact that patent statistics and economic statistics are organized according to different classifications. Patent statistics follow the International Patent Classification (IPC), which is a technology-based classification. When firms or other entities file for a patent, they must identify the IPC technological areas to which their inventions belong. It is that information that is used in the patent statistics. In contrast to that, most economic data (value added, R&D investment, employment figures etc.) are organized according to ISIC-type industrial classifications, which differentiate the economic sectors according to the product markets where they their goods and services are commercialized.

These two types of classification (technology- and product-based) have not allowed for wide cross-section analyses of the sectoral determinants of patenting activities. The only exception to this is a small number of academic surveys that have tried to relate patenting performance and the sectoral belonging of firms. Two of those surveys were carried out in the US (the ‘Yale Survey’ and the ‘Carnegie Mellon Survey’) and another one in Europe (the ‘PACE Survey’). While these surveys have produced some very interesting and enlightening results, they suffer from the fact they cover just a few hundred firms, selected in accordance to their R&D and output size. Given this limitation, the results of those surveys shall be seen as representing only the leading strata of the industrial fabric and as not covering the behavior of the overall business universe.

Recently however the OECD has made public the “OECD Technology Concordance - OTC” database that organizes patent statistics on an industrial basis, in accordance to the presumed sectors of origin of the patents. This was possible by analyzing to which sectors a patent with a given IPC code ‘belongs’. As that code has been found in patents filed by firms belonging, for example, to sectors A, B and C, in proportions of respectively a%, b% and c%, probabilities equal to those proportions are attached to each patent holding that code. The use of appropriate software allows then for an automatic re-classification of all patents based on the respective probabilities of belonging to different sectors.

Despite this OTC database being a big step forward in the direction of allowing for an extensive analysis of the sectoral determinants of patenting activities, an important hurdle still remains: the OECD has only supplied information on the “dependent variable” (patenting by sector of origin), while no immediate information exists in what regards the “independent variables” (the possible patenting determinants).

This paper is an attempt of overcoming that limitation, by bringing together information from more than one source to analyze in conjunction with the ISIC-based patenting data supplied by the OECD. In contrast with previous work that approached the analysis of the sectoral determinants of

¹ According to an article on The Economist of 20th of October 2005, it is estimated that 75% of the shares’ value of firms listed in US stockmarkets stems from their intangible asstes, while that value in 1980 was 40%.

patenting based on partial samples, we will be offering a generalization to the whole business universe. Further, our analysis will be carried out for 10 advanced economies, being two of them from North America (US and Canada), seven from the European Union (Denmark, Finland, France, Germany, Italy, the Netherlands and the UK), and one from Asia (Japan).

In the sequence of this introduction, we will briefly survey in the next section the literature that has analyzes patenting activities in relation to the sectoral belonging of business firms. That survey will allow us to identify the major arguments in the literature, helping to establish our analytical framework. Section 3 will concentrate on methodological aspects. The OECD OTC database is described and the other information sources that will be used are also presented. Next in section 4 we will present several tables and figures with information on the technological specialization of each of the 10 economies and their respective sectoral performances. In section 5 we carry out an econometric exercise on the sectoral determinants of patenting. Finally section 6 concludes.

2. What does the literature tell us?

The research based on the 1984 Yale survey was a big step forward in recognizing the existence of different sectoral behaviors in what concerns patenting activities by business firms. Firms belonging to different sectors put different values on patents in terms of their potential for appropriating the returns on R&D and other innovative activities (Levin et al. 1987). This is the reason why many innovative firms tend to favor other appropriability mechanisms rather than patents to protect their innovations. Further it was shown that firms, irrespectively of their sectors of origin, tend to use more patents to protect product innovation than process innovation.

These results have generally been confirmed by other similar studies carried out both in the US and elsewhere more recently. The Carnegie Mellon Survey (Cohen et al. 1996; Cohen et al. 2000) was based on a slightly larger sample than the original Yale Survey (1478 *versus* 650 directors of the largest R&D business performers in the US). The PACE survey tracked the patenting performance of 604 of the largest and most innovative European firms. For 19 sectors it was shown that no significant link exists between R&D intensity and patenting levels. Significant differences exist at the sectoral level on what regards product patents, but the same does not hold for process patents (Arundel & Kabla, 1998).

Research in the same vein has shown that the international involvement of firms may account for their patenting performances (Arundel et al. 1995). This suggests that in addition to technological opportunities also market opportunities affect patenting levels. Further, the fact that different behaviors are found for the same sectors in different countries might be seen as indicating that the organization and historical trajectories of each national innovation system affect patenting patterns.

One important issue that has been tackled in the sequence of the initial Yale Survey is how market structure affects the sectoral patenting propensities. This follows directly from the so-called 'Schumpeterian hypotheses', respectively on market structure and innovation and on firm size and innovation. In general no strong links have been found between those variables. Some studies indicate a positive relationship, others a negative, and others yet show no relationship at all (for a review of the wide literature on this topic see the survey by Simeonidis 1996).

For a sample of 660 of the world's largest and most innovative firms, Patel & Pavitt (1992) found that in 11 out of 16 sectors no significant relationship exists between size and USPTO patenting, in 3 other sectors a positive relationship holds, and in one sector a negative relationship was significant.

Acs & Audretsch (1991) also found that in only two sectors out of 14 they analyzed a positive relationship between innovation and size could be found. This led them to conclude that the study of innovation and size independently of the sectors to which firms belong to makes no sense. What is relevant, in their view, is to analyze the sectoral characteristics at the highest possible level of desegregation for the existing industrial classifications. This conclusion echoes the earlier findings of Pavitt (1984), that analyzing innovation at the 2 or 3 digit level may significantly affect the possible conclusions.

This need for a more careful measurement of the variables used to test the Schumpeterian hypotheses has been reflected in the work of some researchers. Cohen & Klepper (1996) precisely point out that measurement errors may stem from the sort of indicators used (such as absolute or relative values of R&D expenditure, for example). Additionally they point out that smaller and larger firms innovate with different purposes (new final products or application to intermediate products), which might also lead to errors in the relative assessment of innovative activities.

The perception that the technology life cycle impacts strongly on the relationship between innovation and size emerged long ago (Utterback and Abernathy, 1975; Abernathy and Utterback, 1978). According to the paradigm of the dominant design', in the early stages of each technology life cycle firms compete through product innovation. In that stage many small firms attempt to impose their solution as the industry's standard. As the market evolves, and such standard happens to arise, the competition moves on from product to process innovation. In this stage firms compete on costs and not so much on product differentiation. This eventually leads to an oligopoly solution, in which economies of scale are critical for the surviving firms remaining competitive. The awareness of such life cycle dynamics contributes to understand why the so-called Schumpeterian hypotheses have found so little empirical support.

Similar dynamic argumentations have emerged to a certain extent on other more recent literature on the strategic motivations behind patenting. New firms that have entered the market recently seem to put more value on patents than existing firms, mainly for reputation reasons (Hall 2003).

Evolutionary approaches have also emphasized how 'time' affects innovative behavior. Malerba & Orsenigo (1996; 1997) point out that as firms grow older they tend to consolidate their processes into established routines. As the technology matures, firms will therefore transfer the tacit knowledge associated with the technological opportunities they had initially exploited into codified knowledge. It is not difficult to recognize that the same sort of process may happen at the sector level as it evolves through its life cycle, with evident impacts on both appropriability conditions and patenting activities.

3. Methodological steps

As it was indicated in the introductory section, this investigation is possible after the delivery of the "OECD Technology Concordance - OTC" database in March 2002, which made available patenting data on a sectoral level. The analysis we carried out will relate this sectoral OTC data with information about the possible determinants of patenting.

As the database was delivered, an initial report provided the methodological details of the OTC database (Johnson 2002). The method that was used takes in consideration the International Patent Classification (IPC) code of both product and process inventions for which patents have been filed. The application to each patent of the 'OECD Technology Concordance' (OTC) allows for transforming the IPC codes into ISIC codes, therefore allocating each patent to one or more than one industry at a time.

In the basis of the OTC two main works can be found: the previous ‘Yale Technology Concordance’ and the analyses carried out by the Canadian Intellectual Property Office between 1972 and 1995. The work of the Canadian IP Office consisted in observing individually patents belonging to different IPC codes and finding out from which sectors they originate. This allowed for establishing a correspondence between different IPC codes and SIC (Standard Industrial Classification) codes, which latter were transformed into ISIC (International Standard Industrial Classification) codes. Each IPC code can correspond to several ISIC codes, as a given technology might originate simultaneously from different sectors. This led to the identification of the ‘probabilities’ of each patent belonging to different sectors. This original work of establishing the concordances, which was done by analyzing individually each patent, was latter substituted by the application of the OTC software. The OTC software is based on an algorithm that takes in the observed probabilities to allocate automatically the patents to different sectors. It was the application of this software that led to the delivery by the OECD of the OTC database with information for 1990-1996.

As that database only integrates patenting data information, the economic data that we use to analyze the sectoral determinants of patenting stems from other sources. The sources used are described in box 1 below. All the sources except one have a common origin, which is the OECD.

Box 1. The information sources

The **OECD OTC Patent Database** contains information on patents filed in the European Patent Office, by industrial sector (ISIC Rev. 3), deriving from the application of the OTC (OECD Technology Concordance) method. The information is available for 30 countries for 1990-1996. This database was released in March 2002.

The **OCDE – STAN ANBERD Database** provided the R&D investment information by sector (ISIC Rev.3). The information available is for 19 countries in the period 1987-2001. We used the version of this database released in 2003.

The **OCDE – STAN Personnel Database** was used to obtain information on R&D employment by sector (ISIC Rev.3). We have used the number of researchers in R&D activities. No information is available on this variable for the UK. The information available is for 26 countries in the period 1981-2004. We used the version of this database released in 2004.

The **OCDE – STAN Database for Industry Structural Analysis** provided information on Gross Value Added, Gross Output, Exports and Total Employment on a sectoral level (ISIC Rev. 3). These variables were used as auxiliary to build several indicators that make the comparisons possible. This database contains information on 26 countries for 1970-2002. We used the 2003 version of the database.

The **OCDE Firm Level Database**, which provides information on the demography of business firms in 10 OECD countries, allowed us to obtain a proxy of industrial structure. The information on this database is available by sector (ISIC Rev. 3) for 1980-2001.

From the **Carnegie Mellon Survey** data available on the paper of Cohen et. al (2000) we collected information on the perception firms from different industrial sectors have with regard to patents as a mechanism for protecting their inventions.

As observed above, the only non-OECD source has to do with data originated by the Carnegie Mellon Survey on R&D made available in the paper of Cohen et. al (2000). We used this source to obtain information regarding the effectiveness of patents as a means of appropriability. That information refers only to the US and was produced for 1994. As a simplification, we will take the perceptions revealed by that survey as valid for the remaining countries in our sample.

The Carnegie Mellon Survey asked the directors of US R&D business labs how they assessed different mechanisms of protection, among them patents, as means for appropriating the returns on R&D. It was this assessment of product and process patents that was taken to build the ‘appropriability’ variable that will be used in section 5. Table 1 below provides the data we have calculated for this variable.

As the diverse sources used did not follow exactly the same ISIC breakdown (different 2 and 3 digits sectors), we had to proceed by creating our own concordance matrix to make compatible the information stemming from those sources. The objective was to have a sectoral sample as disaggregated as possible. However, given the restrictions imposed by attempting to join information from different sources, the result was a breakdown into 17 sectors (see table 2 below).

In building our concordance matrix we took as an initial reference the 36 sectors referred to in the Cohen et. al (2000) paper. A weighting scheme was used, taking into consideration the number of respondents to the Carnegie Mellon Survey in each of those 36 sectors, to aggregate them into the 17 sectors we will be using.²

Through the procedures described above we built our own database with 9 indicators for 10 countries for the years between 1993 and 1996.

Table 1. Patents as a means of appropriating the returns on R&D

Sectors	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Patent ‘Strength’	17,33	22,61	26,15	35,00	30,87	43,18	26,29	24,34	21,41	30,97	32,00	35,63	25,25	21,42	32,25	33,41	27,15

Table 2. The 17 sectors in the analysis

1 - food products, beverages and tobacco	10 - fabricated metal products, except machinery and equipment
2 - textiles, textile products, leather and footwear	11 - machinery and equipment, n.e.c.
3 - pulp, paper, paper products, printing and publishing	12 - office, accounting and computing machinery
4 - coke, refined petroleum products and nuclear fuel	13 - electrical machinery and apparatus, nec
5 - chemicals excluding pharmaceuticals	14 - radio, television and communication equipment
6 - pharmaceuticals, drugs	15 - medical, precision and optical instruments
7 - rubber and plastics products	16 - motor vehicles, trailers and semi-trailers
8 - other non-metallic mineral products	17 - aircraft and spacecraft
9 - basic metals	

4. The data: some main results on patenting performance and technological specialization

Given the novelty of the data we are analyzing, we dedicate this section to the presentation of information on both the sectoral patenting propensities and the technological specialization of the economies. We will carry out this through the presentation of two sets of charts. Further, we will provide each of those charts for 3 world ‘regions’: EU7, North America and Japan. We could have

² We can make our concordance matrix available on request.

provided the charts for each of the 10 countries we are analyzing, but that would be cumbersome for most readers.³ So we decided to aggregate the information for the 7 European countries we are analyzing into the 'EU7' entity, and to aggregate the US and Canada data into 'North America'.

The first set of charts refers to two ratios: patents/gross value added ('patenting propensity') and R&D/gross value added ('R&D intensity', in %). In this first set of charts, we have two charts for each of the 3 'regions'. This first chart refers to the absolute values of those two ratios, but with the absolute values in log scale, for the sake of simplifying the observation. The second chart has exactly the same information as the previous one, but with the difference that the absolute values of both ratios were standardized. In this way one can compare more directly the patenting propensities and the R&D intensities across sectors. Namely by observing whether each of the ratios is much bigger (or smaller) than the other, one can infer about the 'R&D productivity' of each sector. For example, sectors where the bar for the standardized patenting propensity is much higher than the bar for the standardized R&D intensity might be seen as sectors of 'high R&D productivity', as with a given proportion of the total business R&D it is able to generate a higher proportion of patents.

The second set of charts is based on the calculation of specialization indexes.⁴ These indexes compare two ratios, as follows: $(PAT_{ij} / PAT_j) / (PAT_{i,10} / PAT_{10})$, in which PAT is the average number of patents filed at the EPO in 1995 and 1996, i is the industrial sector and j the country (or region) for which we are calculating the index. The '10' on the denominator ratio refers to the sum of the values for the 10 countries in the sample.⁵ The analysis of these indexes provides information about the international technological specialization of the countries, in terms of the patents 'belonging' to each of the 17 sectors we are analyzing.

The observation of the first set of charts (figures 1 to 6) allows one to conclude that generally the sectors with higher R&D intensities are the ones with higher patenting propensities. That is the case of the following sectors: office, accounting and computing machinery; radio, television and communication equipment; and pharmaceuticals (drugs). In contrast there are several sectors which have simultaneously low R&D intensities and low patenting propensities. That is the case of: food products, beverages and tobacco; textiles, leather and footwear; pulp, paper products, printing and publishing; coke, refined petroleum products and nuclear fuel; other non-metallic mineral products; basic metals; and fabricated metal products, except machinery and equipment.

These results apply across the 3 'regions' we are observing. However, it is also clear that the patenting propensities do not follow directly from the R&D intensities in each industry. There is some variation, clearly expressed in the standardized values' charts by the fact that both bars (patenting propensity and R&D intensity) often have quite different sizes. In this variation there are two types of cases worth mentioning. Firstly, the 'low R&D productivity' sectors, which are led by the aircraft and spacecraft sector, followed, although at a distance, by the electrical machinery sector and by the motor vehicles sector. Secondly, the 'high R&D productivity' sectors, which consist of the machinery and equipment industries, chemicals, and the precision instruments sector. This low/high R&D productivity is observed in terms of the patents generated with a given R&D, and may stem from different relative importance of tacit and codified knowledge and of the existence of not accounted for 'informal' R&D activities.

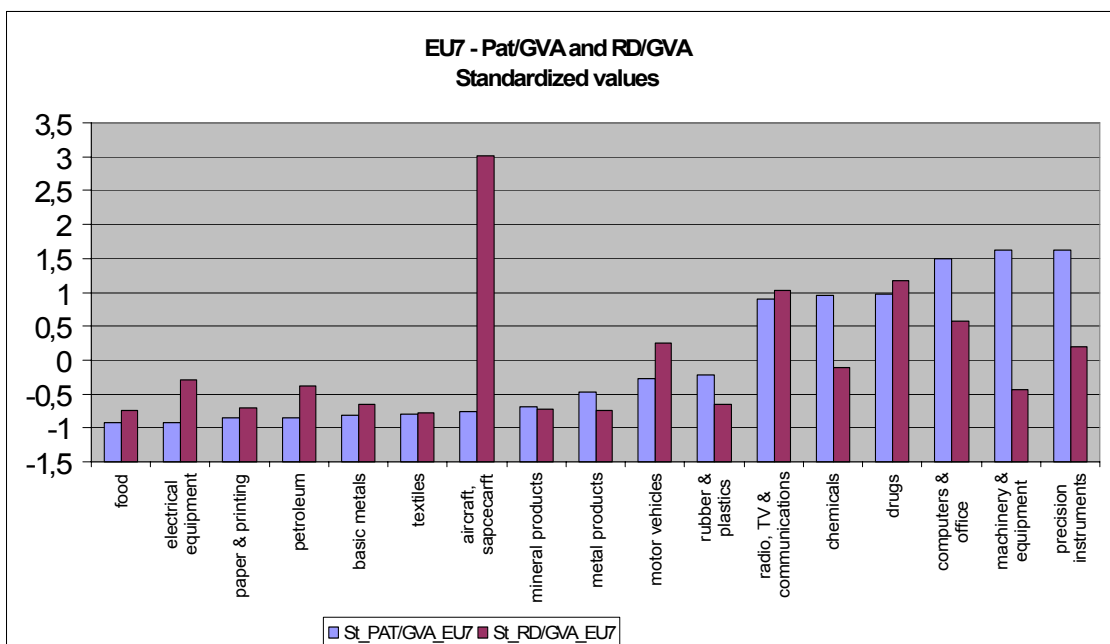
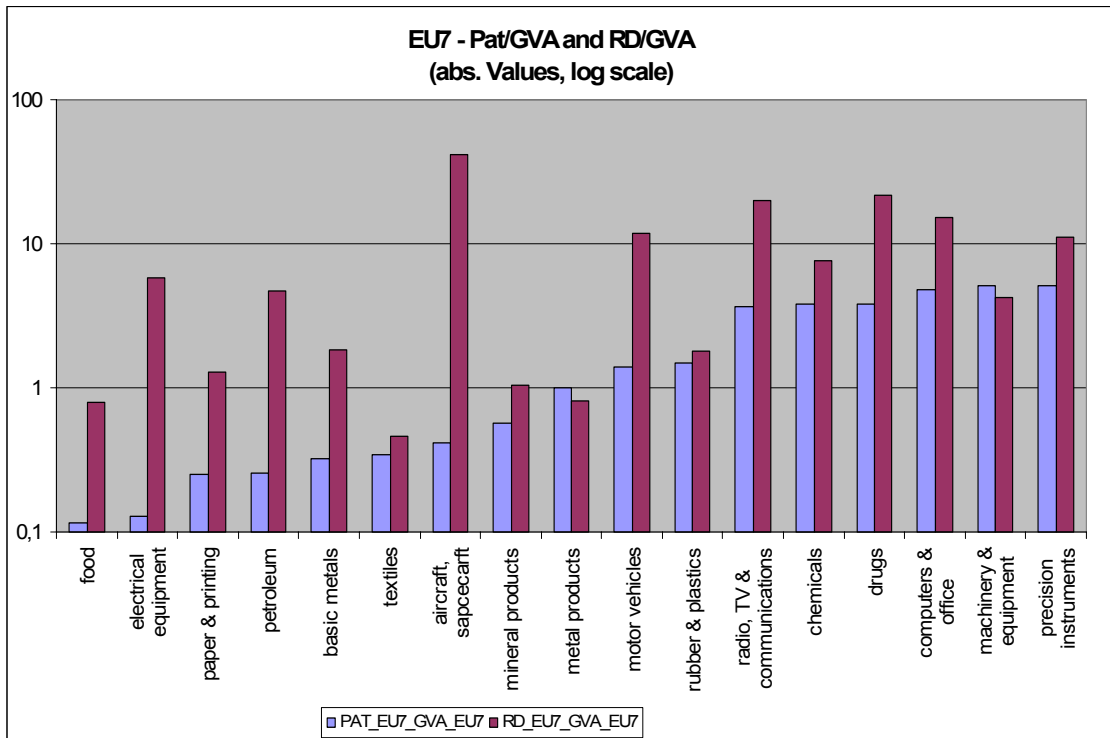
³ We can however supply the individual information for the 10 countries on request.

⁴ This indexes are an analogue of the 'Revealed Comparative Advantage Indexes' used in international trade analyses.

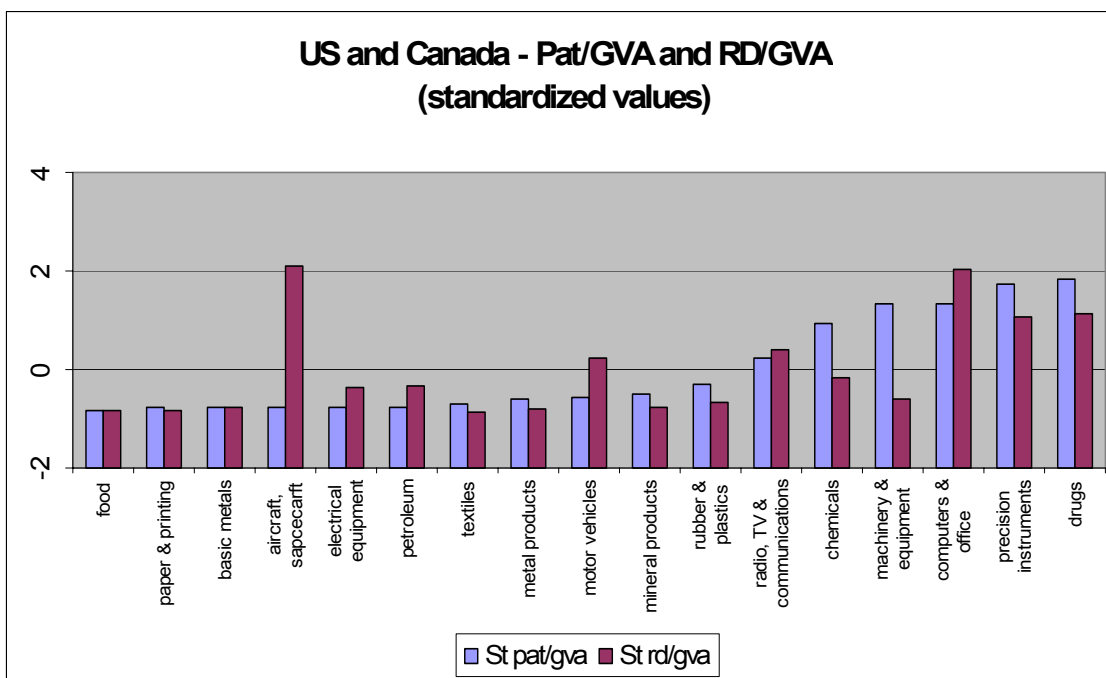
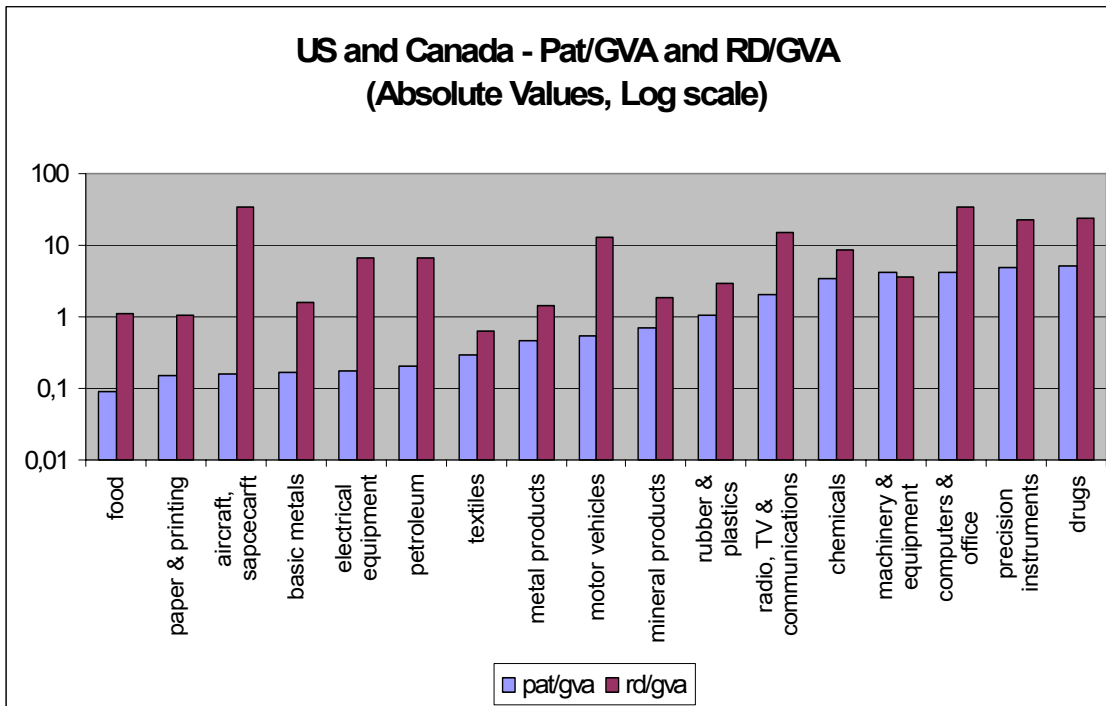
⁵ Normally in international trade analyses in which this type of indexes are used the values on the denominator represent the whole world trade.

The first set of charts still allows one to conclude about the sectors in which each region/country have higher patenting propensities. In all the 3 regions the same six sectors lead the propensities ranking, with the exception of the rubber and plastics sector which also appears among the top industries in Japan. It is possible to notice that the EU7 has a much better performance on the machinery and equipment industries than the other two regions, while the same happens for the leading sector in North America, pharmaceuticals, which is #5 in the EU7 and #6 in Japan.

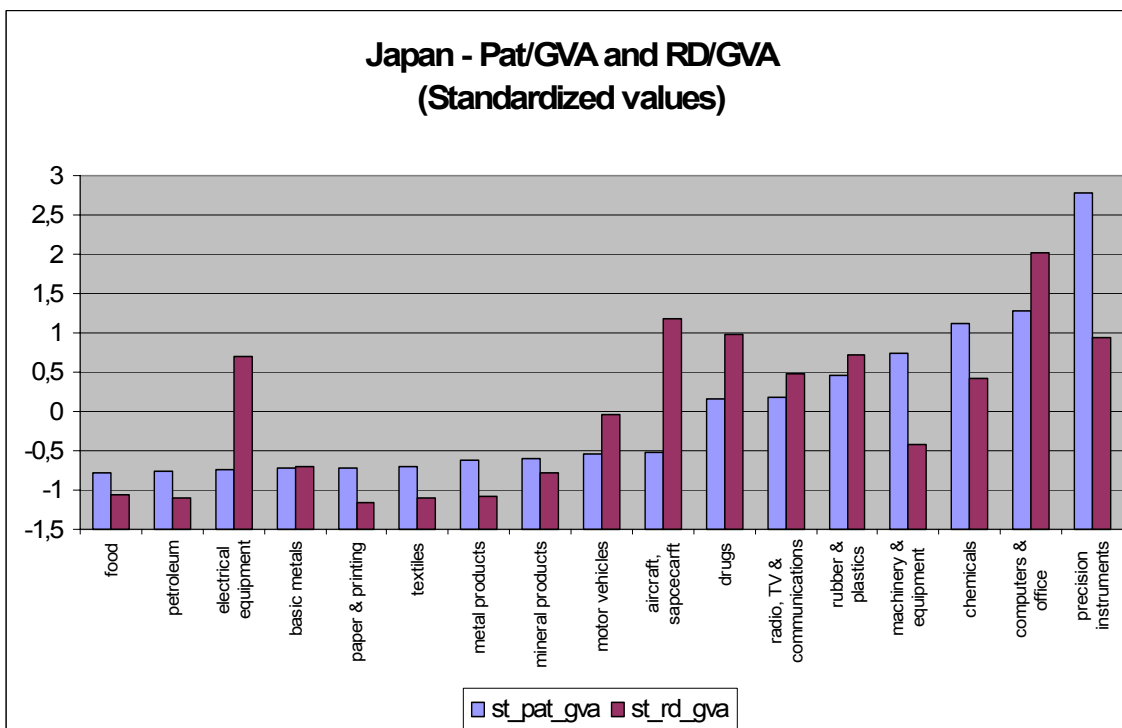
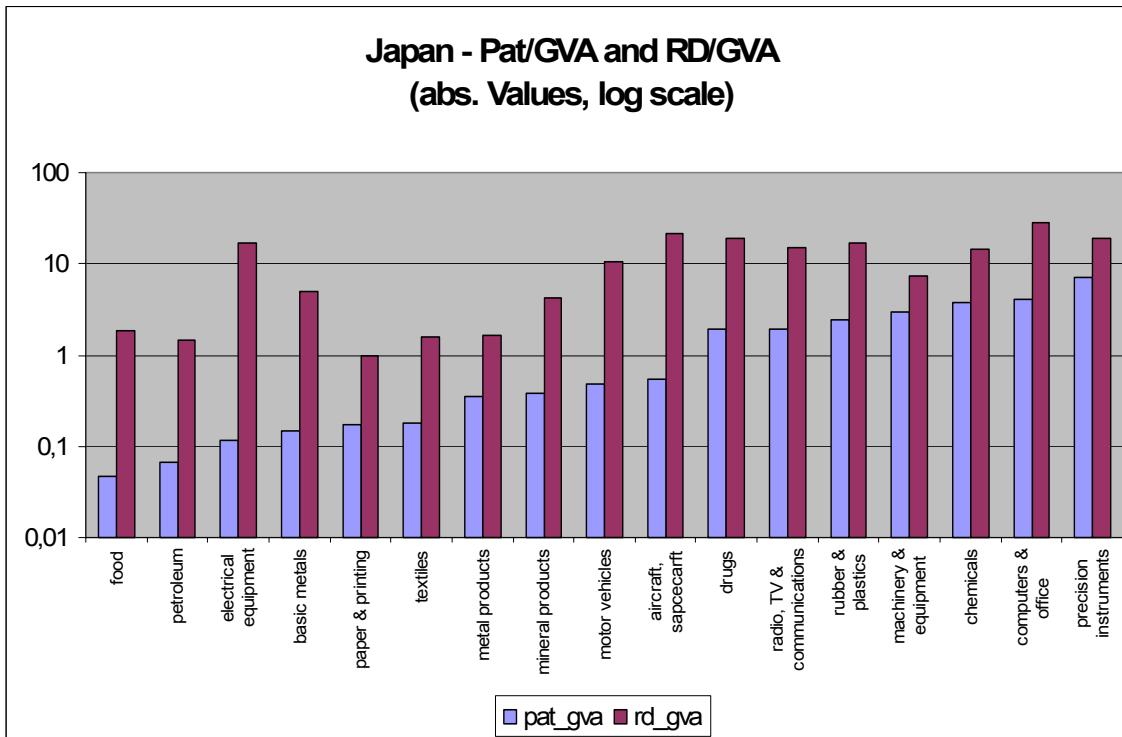
Figures 1. and 2. Patenting and R&D expenditures in the EU7



Figures 3. and 4. Patenting and R&D expenditures in North America



Figures 5. and 6. Patenting and R&D expenditures in Japan



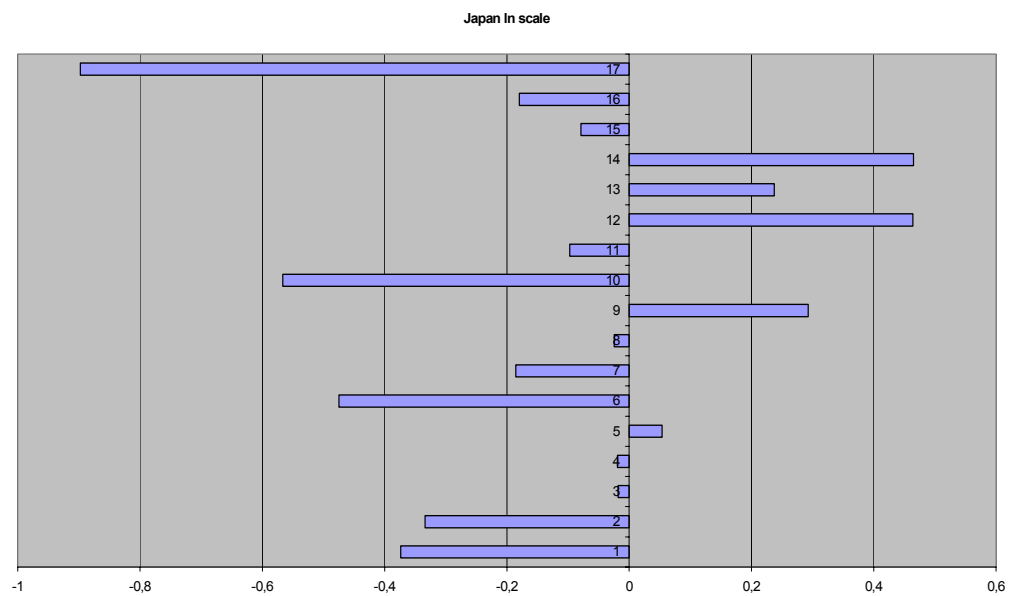
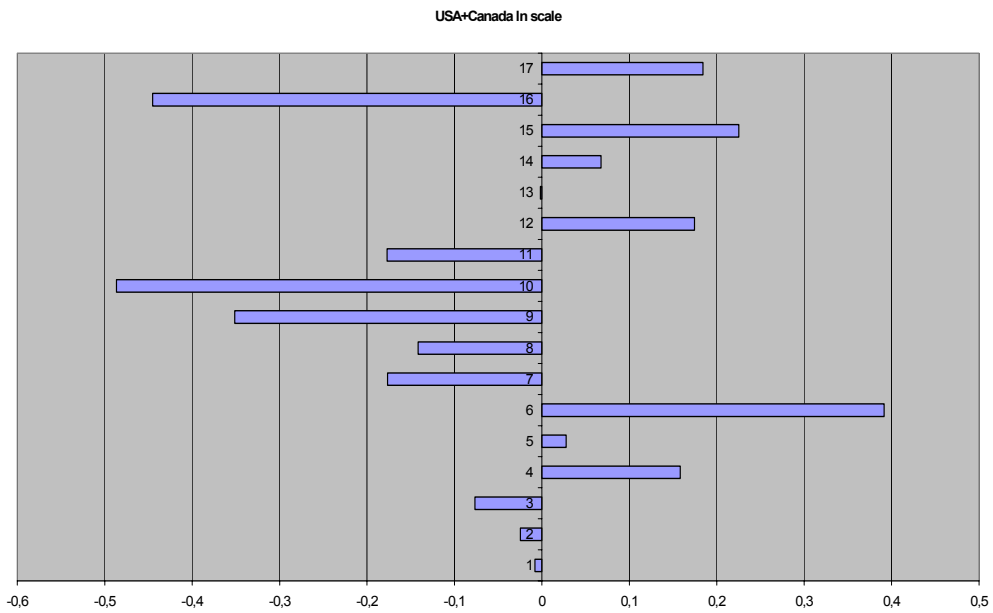
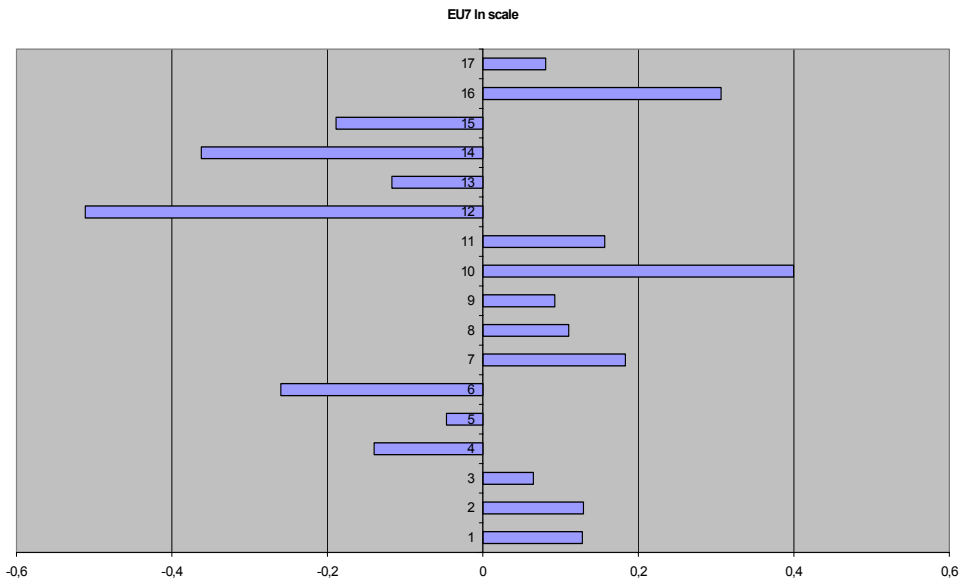
We will now turn to the analysis of the technological specialization as given by the patenting activities by sector. The data is presented in table 3 and in charts 7, 8 and 9 below. It becomes clear from the analysis that the stronger sectors in each of the 3 ‘regions’ are, normally, weaker sectors in the other regions. The EU7 shows a very high specialization in the metal products and the motor vehicles sectors. Both these two sectors are amongst the ones with weakest (negative) specialization indexes in both the US and Japan. In contrast, the two sectors of highest North American specialization, which are drugs and precision instruments, are among the sectors of weakest EU7 specialization and also at least one of them (drugs) is one of the weakest Japanese sectors. Further the two sectors of highest Japanese specialization, which are radio, TV and communications and computers and office equipment, are the two weakest in the EU7.

The analysis reveals that the dominating sectors in the EU7 specialization are medium- and low-tech sectors. In addition to the metal products and the motor vehicles sectors, the EU7 is specialized in the following sectors: rubber and plastics, machinery and equipment, textiles, food, mineral products and basic metals. Both the North American and the Japanese specializations are dominated, in contrast, by high-tech sectors.

Table 3. The international technological specialization of the EU7, North America and Japan

Sector	Country											
	USA	Canada	Denmark	Finland	France	Germany	Italy	Netherlands	UK	Japan	EU7	USA+Canada
1 food	0.9791	1.3565	3.6142	1.0129	0.9615	0.7170	1.1764	3.2008	1.6328	0.6882	1.1365	0.9922
2 textiles	0.9710	1.1106	1.2205	0.6245	1.3880	0.9341	2.4185	0.7002	0.9169	0.7161	1.1380	0.9758
3 paper & printing	0.9222	1.0399	1.3461	1.1065	1.0421	0.9845	1.1753	1.0903	1.2567	0.9819	1.0670	0.9263
4 petroleum	1.1986	0.4203	0.3078	0.2480	0.8342	0.5928	0.7894	0.6643	2.1668	0.9810	0.8695	1.1715
5 chemicals	1.0337	0.8704	0.9636	0.5586	0.8115	1.0593	0.7425	0.7874	1.0605	1.0553	0.9543	1.0281
6 drugs	1.4645	1.8854	2.0465	0.6139	1.0480	0.5320	0.5817	0.7027	1.2221	0.6220	0.7712	1.4792
7 rubber & plastics	0.8309	1.0391	1.1425	0.9629	1.2425	1.2050	1.4253	1.1955	1.0395	0.8306	1.2013	0.8381
8 mineral products	0.8685	0.8559	1.5128	0.6253	1.2636	1.1625	1.0024	1.0138	0.9131	0.9757	1.1166	0.8680
9 basic metals	0.6954	0.9343	0.6959	0.6259	1.2425	1.1814	0.9709	0.7295	0.9792	1.3402	1.0970	0.7037
10 metal products	0.6065	0.8455	1.3141	0.8923	1.4226	1.6662	1.7042	1.2232	1.0875	0.5675	1.4914	0.6148
11 machinery & equipment	0.8282	1.1037	1.0674	1.4924	1.0640	1.2130	1.3672	1.1711	0.9936	0.9072	1.1697	0.8378
12 computers & office	1.2056	0.7757	0.2140	0.4653	0.7126	0.5183	0.5432	0.8735	0.7233	1.5903	0.5996	1.1907
13 electrical equipment	1.0078	0.7322	0.6479	0.8227	1.1876	0.8114	0.7262	0.7951	0.9428	1.2678	0.8896	0.9982
14 radio, TV & communications	1.0805	0.7815	0.2111	1.6023	0.7805	0.5576	0.6211	1.2509	0.7863	1.5921	0.6962	1.0701
15 precision instruments	1.2689	0.8033	1.0062	0.8824	0.8705	0.7716	0.7071	0.9220	0.9691	0.9239	0.8279	1.2527
16 motor vehicles	0.6433	0.5703	0.5511	0.4465	1.5148	1.6160	1.1989	0.5918	0.9520	0.8354	1.3586	0.6407
17 aircraft, sapcecraft	1.1994	1.2840	0.1826	0.3276	2.5340	0.7218	0.5725	0.4443	1.2085	0.4074	1.0842	1.2023
Standard Deviation	0.2335	0.3347	0.8377	0.3749	0.4249	0.3538	0.4922	0.6110	0.3424	0.3344	0.2325	0.2298

Figures 7, 8 and 9. The international technological specialization of the EU7, NA and Japan



5. An econometric model to account for the variation in patenting propensities

This section is dedicated to the presentation of the results stemming from an econometric analysis of the determinants of the sectoral patenting propensity. The model that was put forward was estimated individually for each of the 10 countries that we have been analyzing. It could have been interesting to have the model estimated for the 3 world ‘regions’ we have observed in the previous section, but due to the lack of appropriate data for some of the variables included in the model for some of the countries, that was not possible.

The dependent variable is the patenting propensity by sector, with the number of patents stemming from the OTC database described before. We considered two alternative indicators for patenting propensity, both in log form: the number of patents per unit of Gross Value Added; and the number of patents per worker employed. As the latter tended to generate better econometric performances, it was kept in the results we present below. The value in the numerator is an average of years 1995 and 1996, while the value on the denominator is an average of years 1993 and 1994.

The independent variables stem from 4 major arguments we decided to include in our analytical framework. We consider that the sectoral patenting propensity might stem from: the overall R&D effort; the need for protecting inventions in foreign markets; the market structure; and the appropriability conditions in the industry.

The first variable is therefore called simply ‘EFFORT’. EFFORT is the product of R&D intensity ratio (R&D expenditure/Gross Value Added) by the ratio of R&D workers (researchers) on the total workforce for each sector. For each of those two ratios the numerator is an average of years 1995 and 1996, while the denominator is an average of years 1993 and 1994. We therefore are accepting a lag of two years between the R&D effort and the filing of patents. This variable has to do with the discussion in the literature and in the previous section whether a clear positive relationship exists between R&D levels and patenting propensities at the sectoral level.⁶

The second variable in the model as to do with the involvement in international trade. We tested two alternative ratios for this variable: Exports/Gross Value Added (X/GVA); and Exports/Gross Output (X/OUTPUT). Both of them were calculated as averages of years 1995 and 1996. We think this argument is important for two main reasons: on the one hand by considering the foreign markets we are introducing an element of market opportunity in the model; on the other hand as the patents analyzed are EPO patents, we consider that both for the EU7 countries themselves and for the 3 non-EU7 countries, the EPO patents are filed for reasons of protecting inventions in foreign markets.

The third variable in the model has to do with the appropriability conditions, specifically with the relative effectiveness firms perceive that patents have as means of appropriating the returns on their R&D investments. This variable will be called simply ‘APP’. As explained above this variable stems from the Cohen et al. (2000) paper, and we use the values found for the US in 1994 as if they were ‘universal’, i.e. as if they were about the same in each of the countries we are analyzing. As the literature indicates the appropriability conditions as an important aspect in accounting for the variability in patenting propensity, we use in the model its quadratic form.

Finally the fourth variable has to do with the market structure. We introduce this argument by considering the employment weight of firms with more than 500 workers in the total employment in each sector. This variable, called SIZE, was calculated as an average of years 1993 and 1994. With

⁶ For the UK this variable was simply the R&D intensity, since no data was available on R&D employment for that country.

this we intend to test whether the ‘Schumpeterian hypotheses’ might find support from the evidence we collected.

The general model we estimated had the following specification:

$$\text{Log } PATi/Li = \beta_0 + \beta_1 \text{LogEFFORTi} + \beta_2 Xi/Outputi + \beta_3 APPi^2 + \beta_4 SIZEi + ui$$

Or alternatively

$$\text{Log } PATi/Li = \beta_0 + \beta_1 \text{LogEFFORTi} + \beta_2 Xi/GVA + \beta_3 APPi^2 + \beta_4 SIZEi + ui$$

We observed that technical problems arose from the use of the variables associated with the third argument. For that reason we considered the two alternative specifications above or eventually run the model without that variable. Further, as for some countries we had no information on the variable SIZE, in those cases the model was run without that variable. All the specifications were tested through OLS estimation. Eventual heteroskedasticity problems were assessed through the visual analysis of dispersion charts.

The results of several alternative estimations are presented in detail in table 4 below. As it might be seen all the tested specifications originate models which are statistically significant, with the independent variables explaining on average, for the 10 countries, more than 60% of the variation of the dependent variable.

Table 4. Alternative Econometric Estimations

Dependent Variable PAT/L			Independent Variables							
			C	LOG EFFORT	X/VAB	X/VBP	APP2	SIZE	R2	F
LOG	USA	sig	0,255	0,1		0,852	0,078	0,07	0,688	6,612
		coef	-0,635	0,364		0,0029	0,00079	-0,0016		
	USA	sig	0,236	0,016			0,049	0,057	0,687	9,508
		coef	-0,602	0,392			0,00076	-0,0016		
	CANADA	sig	0,005	0,18		0,847	0,012	n.a.	0,492	4,201
		coef	-2,801	0,245		-0,0013	0,0009			
	CANADA	sig	0,003	0,15			0,009	n.a.	0,491	4,176
		coef	-2,787	0,23			0,001			
	DENMARK	sig	0	0,24		0,62	0,026	n.a.	0,611	6,797
		coef	-1,142	0,125		0,0008	0,0008			
	DENMARK	sig	0	0,06	0,095		0,009	n.a.	0,682	9,302
		coef	-1,077	0,191	-0,0006		0,0009			
	DENMARK	sig	0	0,16			0,019	n.a.	0,603	10,631
		coef	-1,115	0,139			0,0008			
	FINLAND	sig	0,002	0,006		0,78	0,028	0,03	0,685	6,524
		coef	-1,506	0,533		0,0012	0,0009	-0,0014		
	FRANCE	sig	0,01	0,095	0,953		0,1	0,249	0,617	4,843
		coef	-1,097	0,292	-0,00012		0,0007	-0,00073		
	FRANCE	sig	0	0,018			0,059	0,23	0,617	6,992
		coef	-1,106	0,285			0,0007	-0,00073		
	ITALY	sig	0,003	0,077		0,303	0,033	0,1	0,667	6,009
		coef	-1,312	0,261		0,0067	0,0008	-0,0012		
	GERMANY	sig	0,005	0,287	0,954		0,058	n.a.	0,523	4,753
		coef	-1,132	0,177			0,0007			
	GERMANY	sig	0,001	0,1			0,038	n.a.	0,523	7,675
		coef	-1,141	0,17			0,0007			
	NETHERLANDS	sig	0,004	0,386		0,165	0,082	n.a.	0,495	4,245
		coef	-0,989	0,108		0,0012	0,0006			
	NETHERLANDS	sig	0,006	0,424			0,039	n.a.	0,411	4,875
		coef	-0,958	0,103			0,0007			
	NETHERLANDS	sig	0,005			0,16	0,021	n.a.	0,464	6,049
		coef	-0,9			0,0011	0,0007			
UK	sig	0,001	0,977 (a)		0,452	0,039	n.a.	0,464	3,748	
	coef	-1,488	0,009		0,0052	0,0008				
UK	sig	0	0,441 (a)			0,043	n.a.	0,439	5,478	
	coef	-1,305	0,171			0,0008				
UK	sig	0			0,27	0,014	n.a.	0,464	3,751	
	coef	-1,494			0,0053	0,0009				
JAPAN	sig	0	0,062		0,085	0,01	n.a.	0,747	12,781	
	coef	-1,969	0,279		0,015	0,0009				

Notes:

- (1) n.a.= non available – for that country no data was available for that variable;
- (2) (a) the variable Log R&D/GVA was used as an alternative to LogEFFORT, since no data on R&D employment was available for the UK;
- (3) By analyzing the 'Condition Index' computed by the statistical software, one concludes that no multicollinearity problems affect the estimations (in all cases Condition Index < 30).

Next we finalise section 5 by commenting the main results of the estimations.

It is interesting to note that despite the fact highlighted in the previous section of the patenting propensities do not always coinciding with the R&D intensities, the econometric estimations show that in all circumstances these two variables are positively associated. Although, probably as a result of that variation, that relationship is only significant for 6 out of 10 countries.

The most important conclusion stemming from the econometric analysis, however, is that the variable that has the highest impact on the patterns of sectoral patenting is the appropriability conditions. The coefficient for this variable is always positive and significant, two times at the 1% level, 4 times at the 5% level and the remaining 4 times at the 10% level. This finding reveals therefore the critical importance of the appropriability conditions for firms belonging to the different sectors deciding either to patent or not. The policy implications derived from this conclusion are obvious, namely in terms of how policies aiming at stimulating patenting should be designed.

Another important conclusion as to do with the variable associated with market structure. In all the 4 cases for which data was available for testing this relationship, the sign of the coefficient is negative and in 3 of those cases it was statistically significant. This might be seen as indicating that the ‘Schumpeterian hypotheses’ do not receive support from the patenting data that was analyzed.

In relation to the fourth argument included in our model, there was no confirmation that the sectoral variation of patenting propensities might be significantly affected by the need to protect innovations in foreign markets. An exception to this rule however is the Japanese case, for which a positive significant relationship was found.

6. Final remarks

6.1. Patenting propensity and R&D

The main objective of the paper was to analyze the determinants of patenting propensity across different industrial sectors. While for international comparisons of patenting levels one finds a very high correlation between such levels and the amount spent on R&D, the same relationship does not hold in the same way for intersectoral comparisons.

As matter of fact there are some sectors that have a very high R&D spending and relatively low levels of patents. The most significant case in which that happens is the aircraft and spacecraft sector but the same occurs, although to a much lesser extent, in the electronic equipment and motor vehicles sectors. The opposite happens in the machinery and, but to a lesser extent, in the chemicals and precision instruments sectors, which in relative terms have much higher patenting levels than R&D investment.

The two types of situation described above might be seen as cases of ‘low’ and ‘high’ R&D productivity, respectively. However, what probably happens is that firms in the ‘low productivity’ sectors decide not to patent not for lacking of innovative output but because they rely above all on their tacit knowledge and on other means of protecting their innovations, rather than on patenting.

Together with the two extreme situations typified above, that confirm an important variation in patenting levels at the sectoral level when compared to R&D investments, there are also sectors that behave ‘correctly’, i.e. that have either high or low patenting and R&D simultaneously. The first of these two groups (both high patenting and high R&D) includes the drugs industry, the computer and

office machinery sector, the radio, TV and communication equipment sector, and the precision instruments industry.

6.2. Patenting propensity and the technological specialization of the economies

The analysis of the patenting propensities across 17 sectors for each country led us to several important conclusions, in relation to the patterns of both patenting propensity and international technological specialization. The evidence shows how the national (or regional) innovation systems shape different specializations.

One major conclusion as regards patenting propensity is that in general sectors which spend more (less) on R&D obtain more (less) patents, but there are some important exceptions, of sectors with high R&D productivity and others yet, such as the aircraft sector, with very low R&D productivity. Yet in relation to the patenting propensity, the EU seems to have a higher R&D productivity in the machinery and equipment sector than both North America (US and Canada) and Japan, where these industries rank much lower in terms of patenting propensity. In contrast the sector of higher internal R&D productivity in North America is the drugs sector, which ranks lower both in the EU and in Japan. As for the Japanese case, the sector of higher internal R&D productivity is precision instruments, although this sector also ranks high both in the EU and in North America (#2 in both cases).

The analysis of the specialization indexes also led to important conclusions with regard to the international technological specialization of the economies. In this perspective one is observing how a given sector in a country (or region) performs vis-à-vis that same sector overall in the 10 country sample. Different patterns of technological specialization emerged from this analysis. The EU7 reveals a specialization in medium- and low-tech industries. The sectors of greater EU strength are in general the sectors in which both the North America economies and Japan show a greater relative weakness (revealed comparative advantage indexes below 1), and the opposite also applies. In contrast the 4 sectors of higher specialization of the North American economies are all high-tech industries, being that specialization more prominent in the drugs industry. As for Japan, it also has a specialization pattern dominated by higher technology industries, namely the radio, TV and communications sector and the computers and office machinery sector.

6.3. Accounting for different sectoral propensities

The results of several alternative specifications let us conclude that all estimated models are statistically significant, with the independent variables explaining on average, for the 10 countries, more than 60% of the variation of the dependent variable.

The econometric analysis led us to four main conclusions:

- The appropriability conditions seem to be the most important factor in accounting for the variation in the patenting propensity across sectors;
- The R&D effort is positively associated with the patenting propensity, but the relationship is not strong for most countries or eventually it is even non-significant;
- The 'Schumpeterian hypotheses' seem not to receive support from our data, even though the relationship was only tested for 4 countries; and
- Finally the argument that patenting might derive from the need of protecting inventions in foreign markets, does not receive support from the estimations, with one notable exception (Japan).

6.4. Some methodological implications

In addition to the research conclusions that we have been highlighting, the work carried out evidences several methodological implications that need to be mentioned. Probably the most important problem at this level has to do with the need for a practical validation of the OECD OTC database. As it was said, patenting values in the OTC database are allocated automatically to each ISIC sector through an algorithm based on given probabilities. In these circumstances, such empirical validation would naturally reinforce the conclusions from this type of analysis.

A second point to be made has to do with the need of future similar databases to incorporate in addition to the patenting data the relevant economic sectoral data. That would be important to avoid the hard work of making compatible information from different sources, as it was done in this paper. As some of these sources lack information for some sectors in some countries, one has to implement different strategies of analysis and eventually run slightly different models, as it was done. For the sake of consistency, an integrated database would therefore be an important contribution for future research.

It would also be interesting if such database differentiates patents according to their nature (product or process technologies). Additionally, it might be important to have such database at a much thinner level, since the available aggregation, concentrated on the 2 digit level, may be an important source of distortion of the actual meaning of the analysis.

Finally it would be quite important to extend the available information for a more recent period. The information analyzed refers to a decade ago, and several important changes might have occurred meanwhile. The literature has pointed out insistently how 'time' affects the nature and direction of the technological trajectories in each industry. It would therefore be interesting to assess how the determinants of sectoral patenting propensities might change over time.

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